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PROPELLER-MODULATED RADIATION
FROM EIGHT DIFFERENT SMALL AIRCRAFT
(U)

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U. S. NAVAL ORDNANCE TEST STATION

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China Lake, California

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Target-generated signals in the visible and infrared spectral regions were measured for a group of 10 different civilian aircraft in May 1960. The flight tests were conducted at B-1B Range, U. S. Naval Ordnance Test Station, China Lake, California, at the request of the Federal Aviation Agency. A ground-based, unchopped radiometer system was employed to obtain measurements of the target signals while the aircraft flew prearranged patterns above it. Subsequent analysis of the data yielded signal frequency and harmonic content information. Approximate acquisition ranges were computed from radar and target signal data.

The detector used in the radiometer was an uncooled 10mm x 10mm lead sulfide cell, mounted in the focal plane of a high resolution, 48" focal length, f/6 reflective optical system. The field-of-view of the system was 0.5° x 0.5°. No chopping system was used at the radiometer. Optical filtering was not used, so that the detector operated in the 0.3 x 2.5 micron region. The entire radiometer was mounted on a tripod at B-1B Range and manually pointed at the aircraft targets. A small rifle telescope was used to facilitate the tracking.

The output of the PbS cell was amplified by a transistor amplifier, having a flat frequency response from 35 to 1500 cycles. Overall gain of the amplifier was adjustable in steps of 10 from 50 to 50,000. This amplified signal was recorded on a magnetic tape recorder for later analysis.

During the tests, the various aircraft made passes from south to north and from north to south along the Naval Ordnance Test Station B-1B flight line. In general, the sun was about 45° east of the flight path and at a vertical angle of 45°. On clear days, the sky to the south was brighter than that to the north. Thus for tail-on north-south and head-on south-north passes, the target would be against a brighter sky. On cloudy days, a brighter background was presented by sunlight reflected from clouds to the north.

One flight was made with a Beechcraft F35 Bonanza just after sunset. This test was conducted to show effects of sky intensity on signal level. The results clearly showed that detection ranges decreased rapidly as the sky darkened.

Equipment difficulties made it impossible to obtain data on two aircraft, the Cessna 172 and the Piper Apache.

Acquisition ranges were based on a 3 to 1 signal-to-noise ratio, as measured from the taped data. The time of flight from this point to the instrumentation location, multiplied by the ground speed, determined by radar, gave the range.

Fundamental frequencies of the signals were determined with a Hewlett-Packard 302-A Wave Analyzer. Simultaneous measurement of the relative amplitudes of the signal harmonics was accomplished with a Panoramic LP1A Wave Analyzer.

Table I presents characteristics of these various aircraft pertinent to these tests. A comparison of the computed and measured fundamental frequencies is also given in this table.

The fundamental frequency is given by the following formula:

$$F = \frac{RPM \times N \times G.R.}{60}$$

Where F is the fundamental frequency in cps

RPM is the engine speed in RPM

N is the number of blades per propeller

G.R. is the gear ratio between engine and propeller

Figures 1 through 5 present relative intensity data of the signal harmonics in voltage db, referred to the fundamental as 0 db. Data is presented as a function of heading and aspect to show the effects of these parameters.

Figure 6 shows the acquisition ranges for the various aircraft as a function of heading and aspect.

CONCLUSIONS

A propeller-driven aircraft produces a strong a.c. signal, detectable in the short-wave infrared and visible regions. The source of the signal is the background radiation chopped by the propeller. The frequency of the signal is determined by the rotational speed of the propeller and the number of blades in the propeller.

The signal is rich in harmonics; however, it does not appear likely that a recognizable signature for each airplane can be determined. The number and relative amplitude of the harmonics is dependent on background, aspect angle, number of engines and degree of illumination (sun glints, etc.).

The range at which the airplane may be detected by an unchopped system depends upon the type of background, time of day, type of aircraft and aspect angle. With the equipment used for these tests, the aircraft could easily be detected at ranges of from 10 to 20 thousand feet. Use of a system having a narrower electronic bandwidth would increase the acquisition range.

Although no exact measurements were made during these tests, ranges of approximately 7 to 10 miles were noted with the flashing beacon light on several of the airplanes. This light was readily detectable under all conditions, day or night.

Joseph J. Adler

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CHARACTERISTICS OF AIRCRAFT AND FLIGHT CONDITIONS FOR FAA TESTS

Airplane	No. of Engines	No. of Blades per Propeller	RPM	Gear Ratio	Fundamental Freq. Computed	Measured	Sky Conditions
Aero Commander 560A	2	3	2600	120:77	83.5	83.0	Clear
Beech C18S	2	2	1750	1:1	58.3	58.0	Clear
Beech C50	2	2	2750	120:77	58.7	59.0	Clear
Beech F35	1	2	2200	1:1	73.4	73	Day - clouds Night - Clear
Cessna 172(1)	1	2	2350	1:1	78.2	-	Clear
Cessna 182B	1	2	2300	1:1	76.7	77	Scattered clouds
Cessna 310B	2	2	2250	1:1	75	75	Clear
Douglas R4D	2	3	2050	16:0	57.5	58	Clear
Piper PA22 Tri-pacer	1	2	2350	1:1	78.3	78	Clear
Piper PA23 Apache	2	2	2200	1:1	73.4	-	Clear

(1) No data due to equipment difficulties.

TABLE I

RELATIVE INTENSITY OF SIGNAL HARMONICS

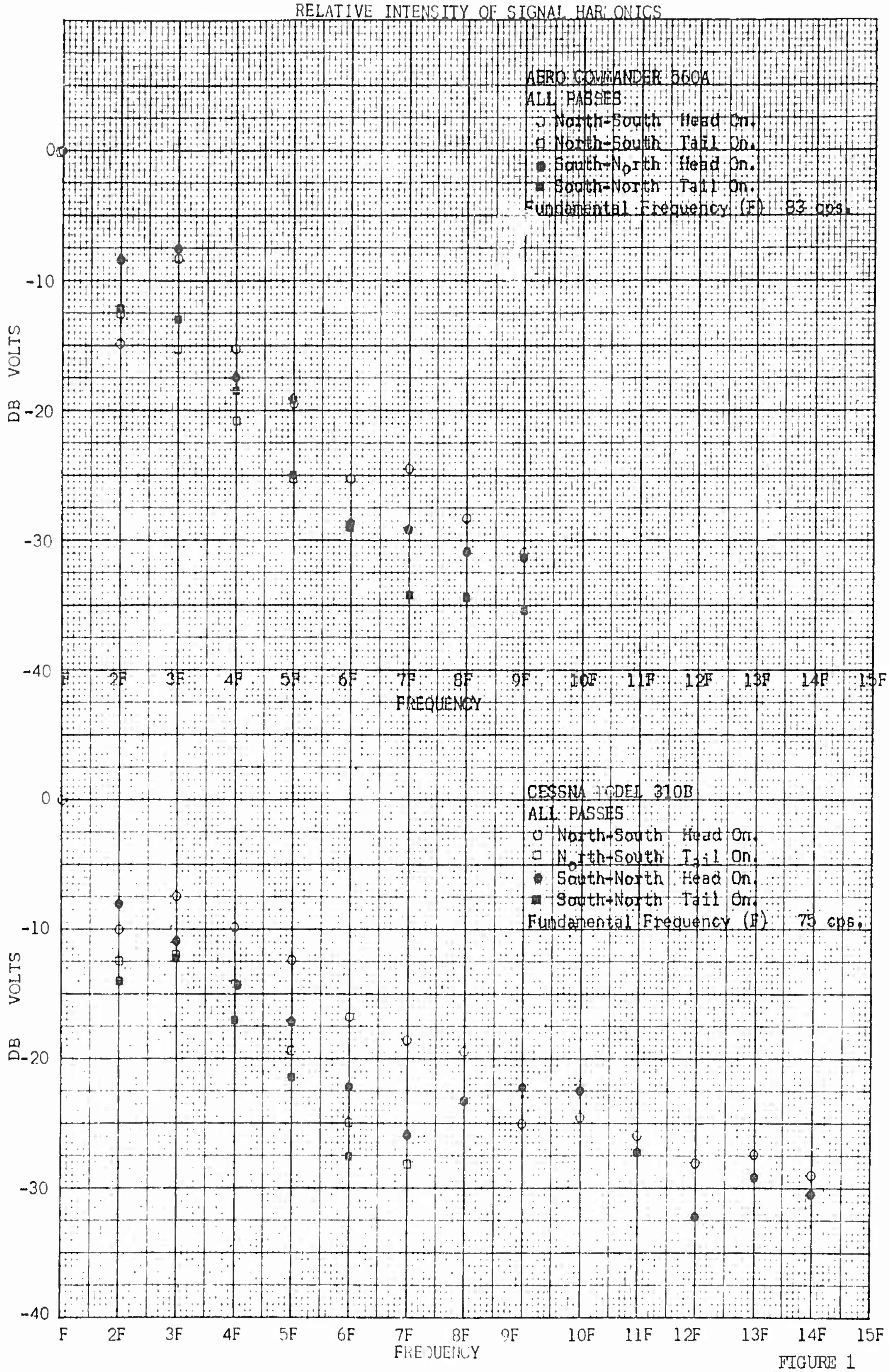


FIGURE 1

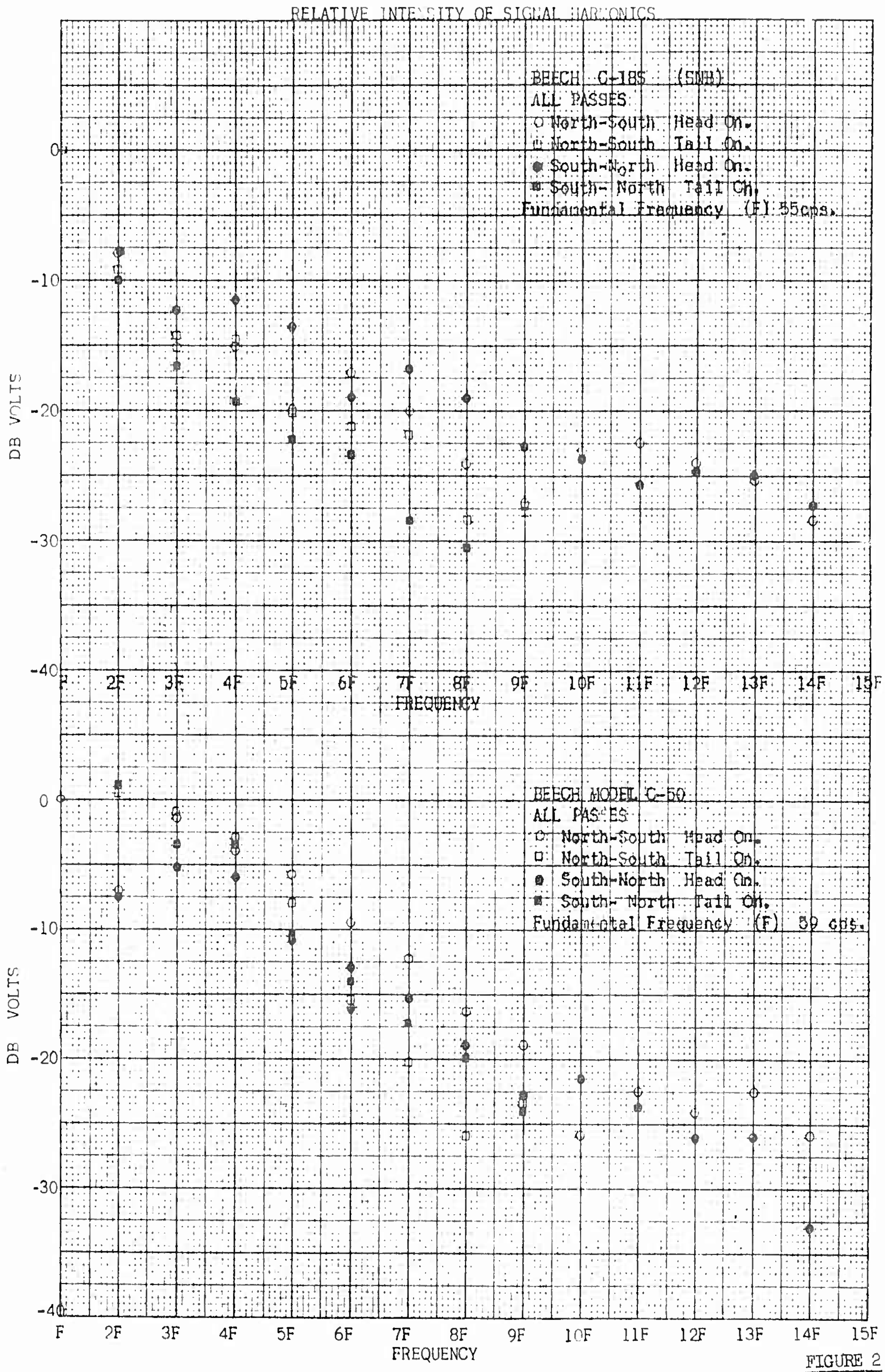
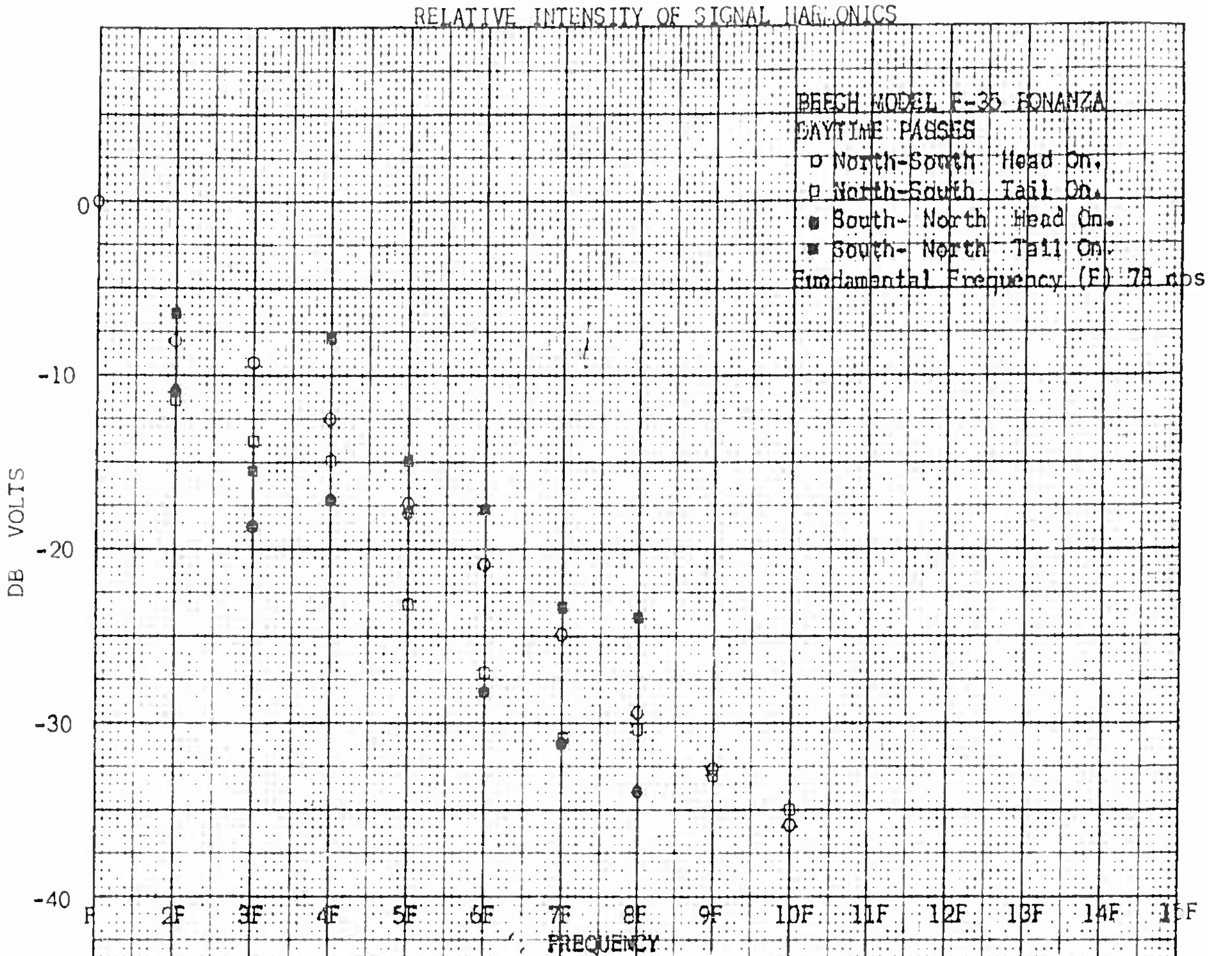

RELATIVE INTENSITY OF SIGNAL HARMONICS
BEECH C-18S (SNB)
ALL PASSES
North-South Head On.
North-South Tail On.
South-North Head On.
South-North Tail On.
Fundamental Frequency (F) 55cps.
DB VOLTS
FREQUENCY
BEECH MODEL C-50
ALL PASSES
North-South Head On.
North-South Tail On.
South-North Head On.
South-North Tail On.
Fundamental Frequency (F) 59 cps.
DB VOLTS
FREQUENCY

FIGURE 2

RELATIVE INTENSITY OF SIGNAL HARMONICS



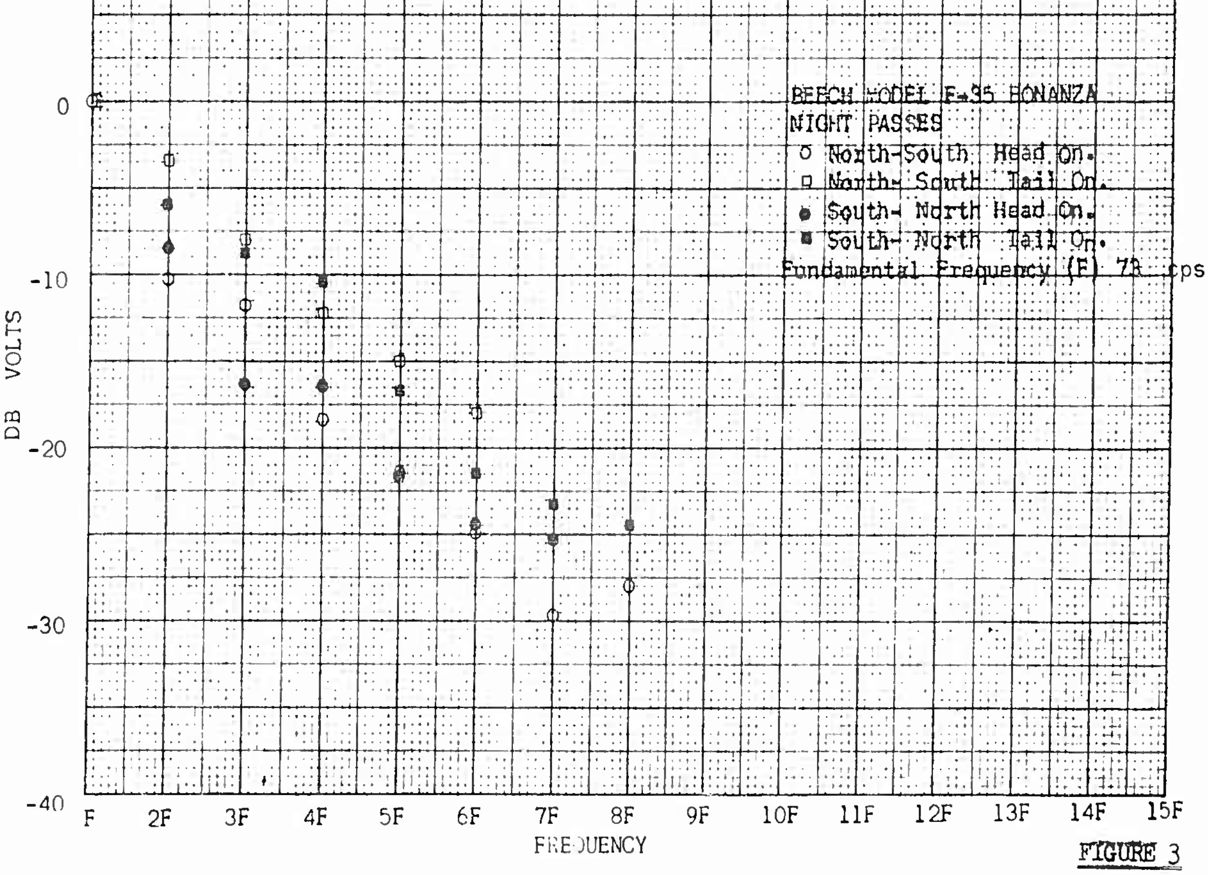


FIGURE 3

RELATIVE INTENSITY OF SIGNAL HARMONICS

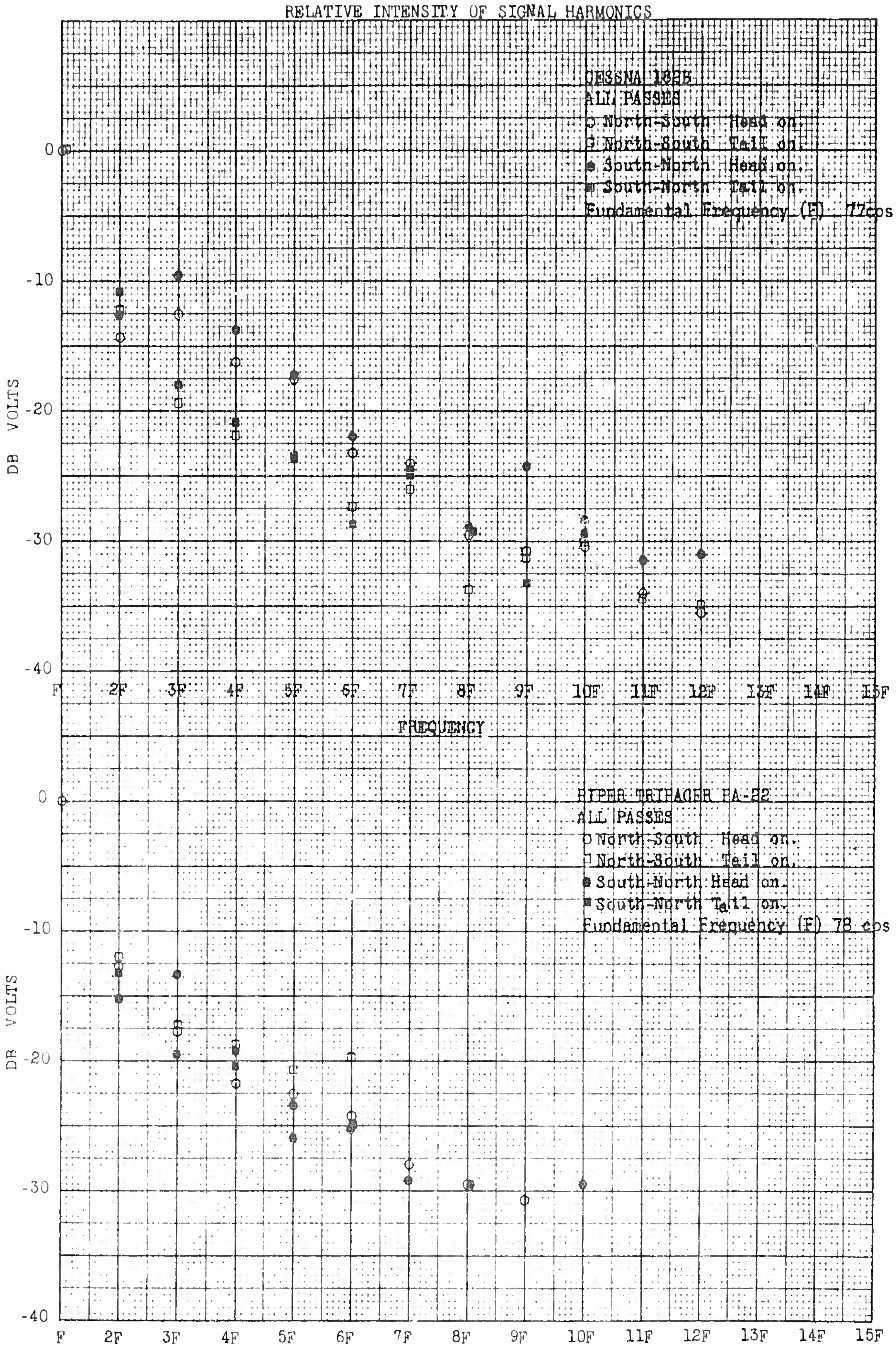


FIGURE 4

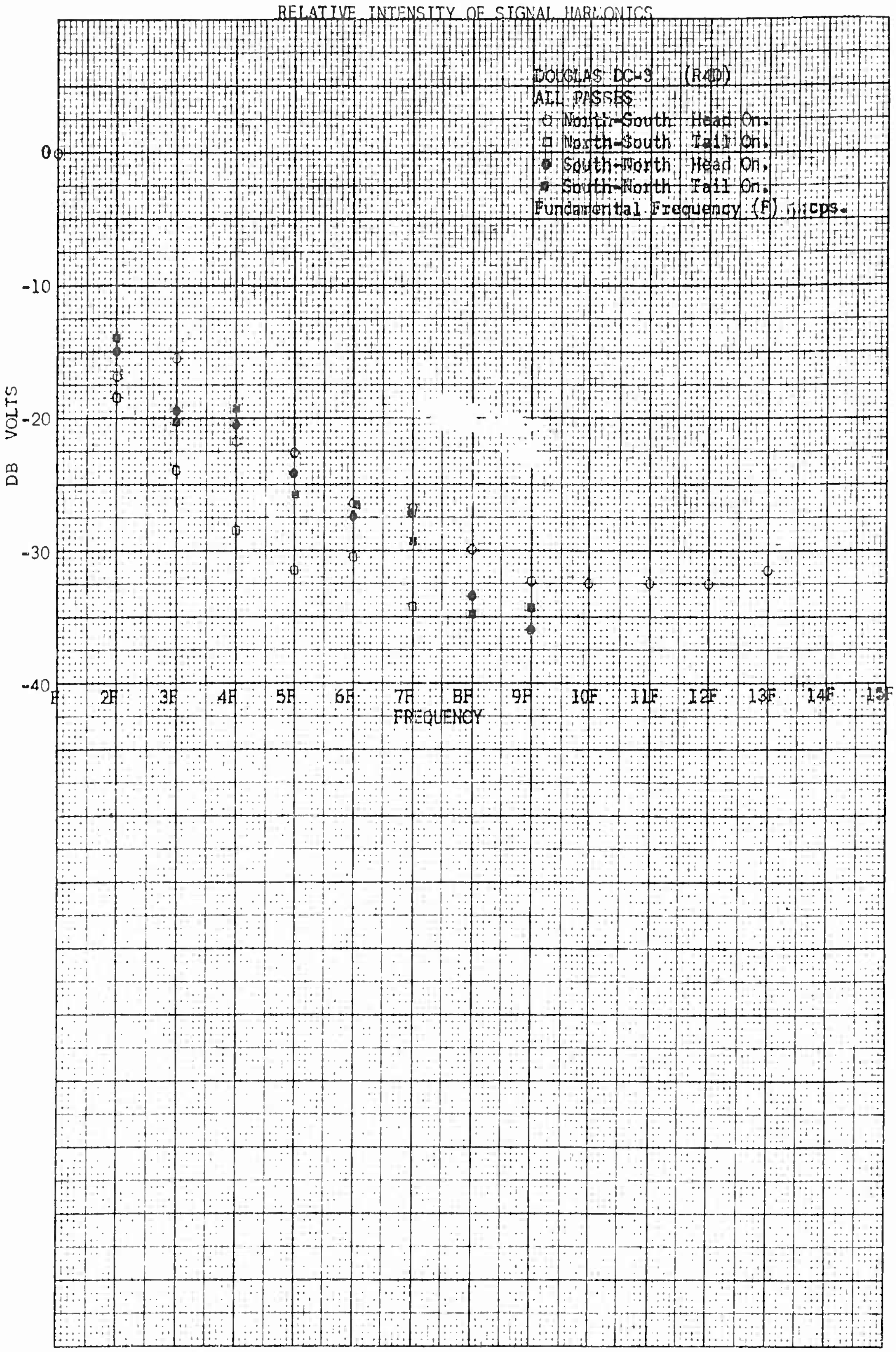

RELATIVE INTENSITY OF SIGNAL HARMONICS
DOUGLAS DC-3 (R4D)
ALL PASSES
North-South Head On.
North-South Tail On.
South-North Head On.
South-North Tail On.
Fundamental Frequency (F) cps.
DB VOLTS
0
-10
-20
-30
-40
F
2F
3F
4F
5F
6F
7F
8F
9F
10F
11F
12F
13F
14F
15F
FREQUENCY

FIGURE 5

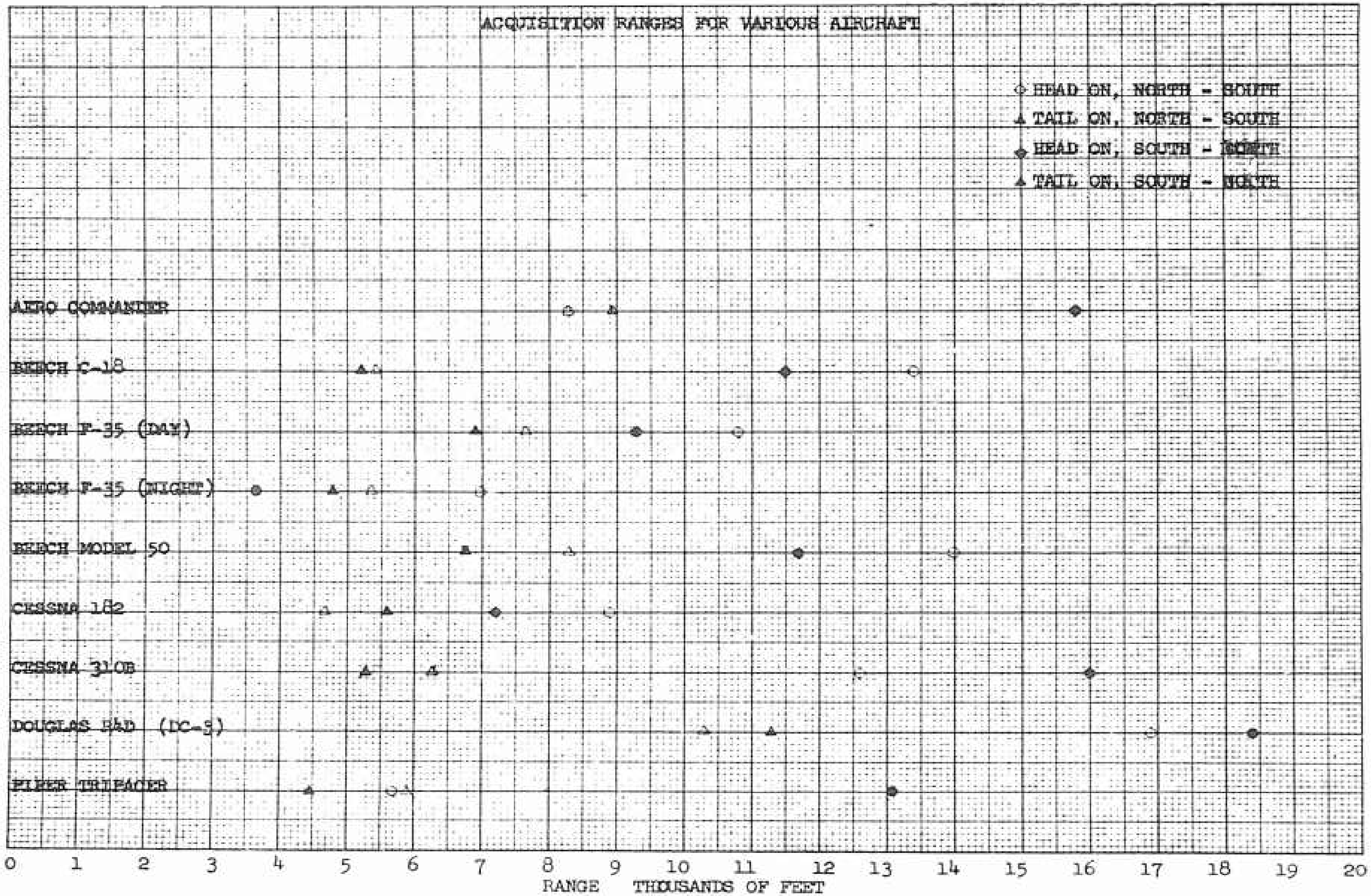

ACQUISITION RANGES FOR VARIOUS AIRCRAFT
HEAD ON, NORTH - SOUTH
TAIL ON, NORTH - SOUTH
HEAD ON, SOUTH - NORTH
TAIL ON, SOUTH - NORTH
AERO COMMANDER
BEECH C-18
BEECH F-35 (DAY)
BEECH F-35 (NIGHT)
BEECH MODEL 50
CESSNA 182
CESSNA 310B
DOUGLAS R4D (DC-3)
PIPER TRIPACER
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
RANGE THOUSANDS OF FEET

FIGURE 6